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RESEARCH ARTICLE

RISK FACTORS ASSOCIATED WITH *SALMONELLA* SPECIES CONTAMINATION OF COMMERCIAL POULTRY FARMS IN JOS, PLATEAU STATE, NIGERIA

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ABSTRACT

We conducted an investigative study to determine the prevalence and risk factors for *Salmonella* contamination of poultry farms in Jos, Plateau State, Nigeria. A standardized questionnaire was used to collate data on farm management practices, demographic characteristics, farm-handlers personal hygiene and clinical information from August, 2012 to April, 2013. Odds ratios were computed using bivariate analysis. Results revealed 10.9% prevalence of *Salmonella* species from the study using standard bacteriological methods. Farm previously contaminated by *Salmonella* (OR48.0; CI 95%2.40-958.0), presence of rodents (OR 11.25; CI 95% 1.19-106.13), movement from one pen to the other by farm-handlers (OR4.38; CI 95% 1.10-33.9), running and parking truck near the entrance to poultry farms ($p < 0.05$) and the use of untreated water ($p < 0.05$) were found to be independently associated with an increased risk of *Salmonella* infection in broiler and layer flocks. Furthermore, the results indicates that application of specific hygiene measures in the farm, such as washing of hands after tending the flocks, use of footbath disinfection when entering the poultry house, may significantly reduce the risk of *Salmonella* infection in chicken and farm-handlers. However, the use of antibiotics and vaccination against *Salmonella* were found to be protective.

INTRODUCTION

Salmonella is a leading cause of bacterial food-borne disease outbreaks in developed countries and is also a public health concern in developing countries (Medeiros *et al*., 2001). Salmonellosis is considered to be one of the major bacterial disease problems in the poultry industry world-wide. *Salmonella* species are responsible for a variety of acute and chronic diseases in both poultry and humans (Majowicz *et al*., 2010; Okwori *et al*., 2013) and infected poultry products are among the most important sources for food borne outbreaks in humans. Isolation of *Salmonella* is reported more often from poultry and poultry products than from any other animal species. The genus *Salmonella* of the family Enterobacteriaceae consists of more than 2,300 serologically distinguishable variants (Yan *et al*., 2003). According to Centers for Disease Control and Prevention, *Salmonella* alone affects about 1.4 million people each year in the United States with about 16,000 hospitalizations and more than 500 deaths annually. In 1996, the United States Department of Agriculture (USDA), Economic Research Services estimated that the total costs for medical care and lost productivity, resulting from food borne *Salmonella* infections of humans was between 0.6-3.5 billion dollars annually (CDC, 2009; Majowicz *et al*., 2010). Other costs associated with salmonellae include various direct expenses producers face as a consequence of *Salmonella* infection in chicken flocks. Control measures such as biosecurity practices, cleaning and disinfecting of facilities, rodent control programs, vaccination, and testing all can significantly increase production costs. Moreover, *Salmonella* contamination of food products can significantly reduce consumer demand and affect producer profits (Namata *et al*., 2008). Commercial poultry constitute one of the largest and most important reservoirs of paratyphoid (PT) salmonellae that can be introduced into human food supply. Controlling paratyphoid (PT) infections has thus become an important objective for the poultry industry from both public health and economic perspectives (Gast, 2003). There has been extensive research related to food safety in every aspect of production, transportation, processing, storage and food preparation.

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However, in spite of the quantity of information available, there are still gaps in our knowledge of food safety and absolute control of salmonellosis in the poultry industry, especially if we consider the entire farm-to-fork production model, with more emphasis to Jos, the Plateau State capital, Nigeria. In addition, Jos has been described as a civil servant state due to the predominance of civil servants, as well as myriad of unemployed graduates who source for means of augmenting their incomes, which has led to the up surge of poultry keeping in the state. Salmonellosis in the poultry industry is to a great extent hindering the achievement of a private sector driven economy and micro stability in Nigeria. In view of this, less attention is given towards foreseeing and preventing the outbreak of the disease in the poultry industry. Hence, prevention of *Salmonella* contamination of broiler/layer flocks requires detailed knowledge of the most important risk factors associated with its presence in the production system. Therefore, our aim was to determine the prevalence and identify the risk factors associated with *Salmonella* contamination of commercial poultry farms in Jos, Plateau State, Nigeria.

MATERIALS AND METHODS

Study area

The study was carried out in Jos city. The area comprised Jos North, Jos South and Jos East Local Government Areas in Plateau State, Nigeria (Figure 1).

Jos North has its headquarters in the state capital situated in the middle belt zone of Nigeria, 9^o 56' N 8^o 53' E with an area of 291 km^2. It has a population of 437,217 with most of the people involved in poultry farming. Jos South has its headquarters in Bukuru town at 9^o 48' 00'N 8^o 52' 00'' E. It has an area of 510 km^2 south of the state capital and a population of 311, 392. The main occupation is agriculture with high population involved in poultry farming. Jos East has its headquarters at Angware. It has an area of 1,020 km^2 and a population of 88, 301. Farming and trading are the major occupation of the people with only few population involved in poultry farming.

Sampling of poultry and poultry farm handlers

The study, which lasted from August 2012 to April 2013, involved 18 commercial broiler/layer poultry farms. Each farm was visited twice and a total of 450 samples, including both poultry (droppings/swab from the surface of eggshells) (180), humans (faeces/hand swab) (180) and feeds (90) were collected. The samples were investigated for presence of *Salmonellae* partly in the Central Diagnostic Laboratory, National Veterinary Research Institute, Vom, Plateau State and partly in the Department of Microbiology, Faculty of Science, Ahmadu Bello University, Zaria, Kaduna State, Nigeria.

Farm management

Prior to the enrolment, voluntary and informed consents were obtained from poultry farm owners and poultry farm handlers.

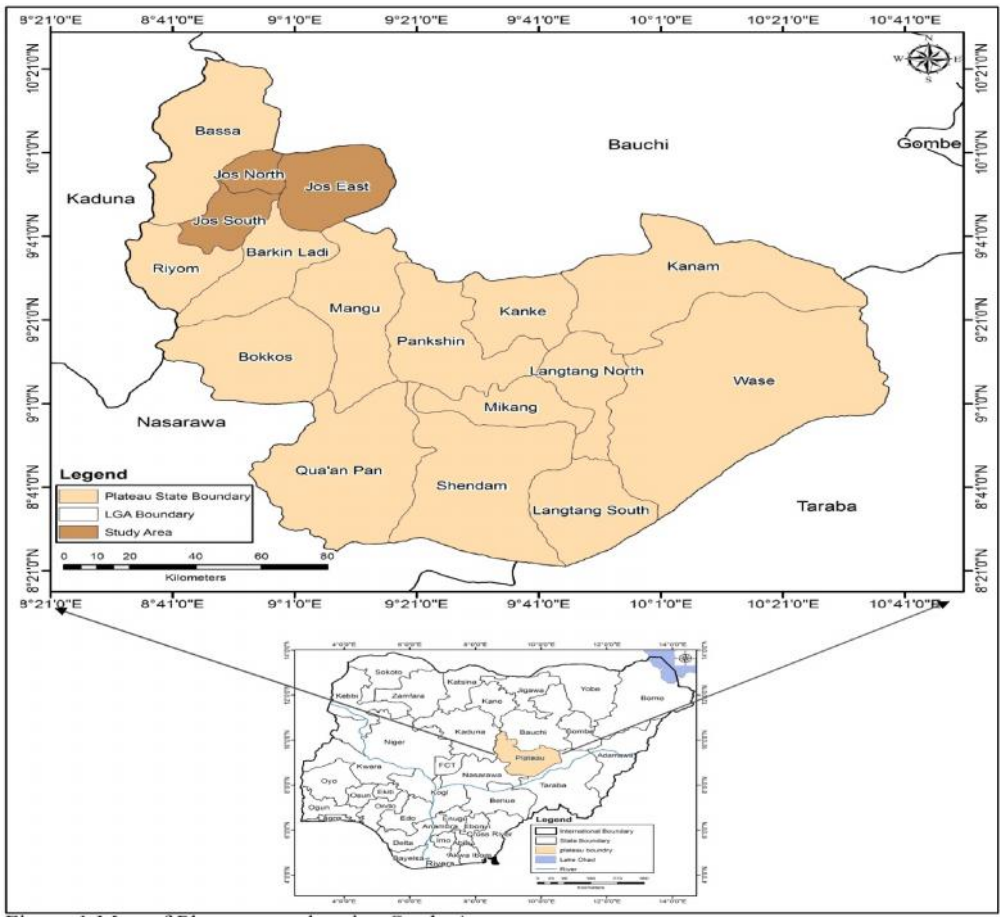

Figure 1. Map of Plateau State, Nigeria

Ethical approval (NHREC/05/01/2010b) was also obtained from Plateau State Specialist Hospital and approval from the Department of Veterinary Services, Ministry of Agriculture, Plateau State. Information on farm management was collected using a structured questionnaire. The information collected included data on vaccination and administration of antibiotics, use of footbath disinfection, presence of rodents and other farm animals, use of treated and untreated water in the farm, the parking of trucks close to farm entrance, previous contamination of farm by *Salmonella*, knowledge of salmonellosis, movement of farm handlers in the farm and other personal hygiene/biosecurity measures taken during the broiler/layer cycles.

Sample processing

Poultry droppings

Twenty five gram of poultry droppings was pre-enriched in 225ml of Selenite Faeces and incubated at 37^{o}C for 24h. Sub culture was carried out by streaking onto *Salmonella- Shigella* agar (Oxoid, UK), Brilliant Green agar (BGA) (Oxoid, UK) plates and Xylose Lysine Desoxycholate (XLD) agar (Oxoid, UK). The cultured plates were incubated at 37^{o}C for 24 to 48h (Whyte *et al.,* 2002; Habtamu *et al.,* 2011; OIE, 2012**).**

Poultry feeds

Twenty five gram of representative samples of poultry feeds was pre-enriched in 225ml of BPW, incubated 37^{o}C for 24h. One milliliter (ml) was transferred into 9 ml of Rappaport Vasiliadis Broth (RVB), incubated at 37^{o}C for 24h. A loop-full of culture from RVB was sub cultured by streaking onto SSA, BGA and XLD agar. The sub cultured plates were incubated at 37^{o}C for 24h (Cox *et al*., 1983; Cardinale *et al.*, 2004).

Faeces from farm handlers

Twenty five grams of faeces from farm handlers was pre-enriched in 225 ml of Selenite Faeces (SF) broth (Oxoid, UK), incubated at 37^{0}C for 24h and sub cultured by streaking onto SSA, BGA and XLD agar plates. The sub cultured plates were incubated at 37^{o}C for 24 to 48h (Whyte *et al.,* 2002; Habtamu *et al*., 2011; OIE, 2012**).**

Hand Swab

Swabs from the hands of poultry farm Handlers were collected and cut with sterile scalpel blade into 10 ml buffered peptone water (BPW) in screw capped bottles, incubated at 37^{o}C for 24 hour for pre-enrichment. One milliliter of this pre-enrichment broth was transferred into tubes containing 9ml RVB, incubated at 37^{o}C for 24h. A loopful of culture from RVB was sub cultured by streaking onto SSA, BGA and XLD agar. The sub cultured plates were incubated at 37^{o}C for 24 to 48h (OIE, 2008; OIE, 2012).

Swabs from surface of egg shells

Surface swabs from eggshells were collected and cut with sterile scalpel blade into 10ml BPW in screw capped bottles, incubated at 37^{o}C for 24h for pre-enrichment. One milliliter of this pre-enrichment broth was transferred into tubes containing 9ml RVB, incubated at 37^{o}C for 24h. A loopful of culture from RVB was sub cultured by streaking onto SSA, BGA and XLD agar. The sub cultured plates were incubated at 37^{o}C for 24h to 48h (Suresh *et al*., 2006; OIE, 2012).

Isolation and identification of S*almonella*

Presumptive isolation of *Salmonella*

The cultured plates, SSA, BGA and XLD agar were examined for the presence of typical colonies of *Salmonella* based on cultural and morphological characteristics, that is, transparent colonies with black centre on SSA and pink colonies surrounded by a red medium on BGA, and small red translucent and or dome-shaped colonies, which may have central black spot due to hydrogen sulphide production on XLD.

Purification of isolates

The isolates were sub cultured onto SSA and nutrient agar for isolation of pure culture and subsequent biochemical characterization.

Biochemical characterization of *Salmonella*

Characterization of the isolates was achieved using biochemical test method described by Snoeyenbos, (1991); Cowan and Steel (1993); Cheesebrough (2001); ISO, (2002), Muhammed *et al.* (2010); Habtamu *et al*. (2011); OIE, (2012). A 24h pure culture of each isolate was used to determine their gram reaction. The following biochemical tests were carried out: Indole test, triple sugar iron test, citrate test, methyl-red test, Voges-Proskauer test, lysine decarboxylase test, ornithine decarboxylase test, urease test, sugar (trehalose, sucrose, inositol, glucose, dulcitol, maltose, mannitol, melibiose, salicin, rhamnose and arabinose) fermentation test and motility test. Isolates were further characterized using Analytical Profile Index (API) 20 E test kit (Biomerieux, France).

Serotyping

Cultures of organisms derived from a pure culture and identified as *Salmonella* by biochemical tests and API 20 E, were serotyped. Serological identification of the *Salmonella* species was carried out using Polyvalent *Salmonella* H antisera (Phases 1 and 2) and *Salmonella* O (Group A-G) antisera (Oxoid, UK; SIFIN, UK).

Data analysis

Data management, entry and analysis were done using Epi Info (version 7.0), program excel (Microsoft® Office Excel 2010, Professional Edition) and SAS software (version 9.0). Analysis of Variance (ANOVA) was used to compare variables while Duncan multiple range test was used to separate the mean. Descriptive statistics was used to describe the result of prevalence analysis. Prevalence was estimated as the number of samples detected positive to *Salmonella* isolation from the

total sample analyzed. Bivariate analysis was used to analyze the risk factors.

RESULTS

Out of the 450 samples comprising human faeces/hand swabs, poultry droppings, swabs from surface of eggshells and feeds tested, 49 were found positive for various species of *Salmonella* in the three local government areas (LGA) accounting to a prevalence rate of 10.9%. Jos South and Jos East LGAs recorded the highest and lowest prevalence rate respectively (Table 1). Out of the positive *Salmonella* isolates, 6 serovars were identified. The serovars and their corresponding number of isolates were: *Salmonella enterica* serovar Gallinarum (*S*. Gallinarum) was found (28), *S. enterica* serovar Typhimurium (*S*. Typhimurium) (4), *S. enterica* serovar Typhi (*S*. Typhi) (10), *S. enterica* serovar Pullorum (*S*. Pullorum) (3), *S. enterica* serovar Enteritidis (*S*. Enteritidis) (3) and *S. enterica* serovar Paratyphi A (*S*. Paratyphi A) (1). There was statistical significant difference ($p < 0.05$) in the number of isolates in Jos South as compared to Jos North and Jos East LGAs with Jos South having the highest number of isolates (Table 2).

Table 1. Prevalent rate of *Salmonella* in the three LGAs studied in Plateau State

LGA	No. of Poultry farms	No. of Samples	No. Positive	% Positive
Jos North	6	150	15	10.0
Jos South	6	150	26	17.3
Jos East	6	150	8	5.3
Total	18	450	49	10.9

LGA: Local Government Area
No.: Number
%: Percentage

Results presented on Table 3 shows that farms whose poultry farm handlers move from one pen to the other (OR 4.38; CI 95% 1.10-33.9) were more at high odds of distributing *Salmonella* from one flock to the other as compared to farms who did not engage in such practices. In addition, the odds of flock being infected was higher in farms that had previous contamination by *Salmonella* (OR 48.0; CI 95% 2.40-958.2), trucks running and parking near the entrance to poultry house ($p < 0.05$) and presence of rodents (OR 11.25; CI 95% 1.19-106.13) in their farms. Poultry farms that used untreated water for their flocks were at high odds of contaminating the chickens with salmonellosis. Plate 1 shows the characteristic of *Salmonella* isolate on Salmonella-Shigella agar, with black centre as a result of hydrogen sulphide production by some *Salmonella* species. Plate 2 shows the characteristic red translucent colonies with black centre by *Salmonella* species on xylose lysine desoxycholate agar. Plate 3 shows the characteristic pale red translucent colonies of *Salmonella* species on brilliant green agar as observed in this study.

However, the bivariate analysis suggested a protective effect with regard to several exposures such as presence of other farm animals ($p >0.05$), use of footbath disinfection when entering the poultry house (OR 0.60; CI 95% 0.03-11.47), vaccination against *Salmonella* infection ($p >0.05$) and administration of antibiotics ($p > 0.05$). Results presented on Table 4 shows the risk factors for zoonotic *Salmonella* infection among poultry farm handlers. The odds of being infected by *Salmonella* among poultry farm handlers were higher in handlers who had no knowledge of salmonellosis (OR 8.25; CI 95% 1.00-85.6). Though, keeping of other avian husbandry at home (OR 2.22; CI 95% 0.25-20.17), washing of hands (OR 3.43; CI 95 % 0.29-39.6) and change of clothing after work (OR 2.50; CI 95% 0.21-29.25) showed high odd ratios, statistically there was no significant association.

DISCUSSION

The overall prevalence rate in this study is slightly higher than that obtained by Muhammed *et al*. (2010) who recorded 9.0% prevalence rate of *Salmonella* associated with chick mortality from hatcheries in Jos, Plateau state. The higher prevalence observed in this study may perhaps be attributed to lack of awareness on the prevention and control of salmonellosis and poor management practices observed in most of the poultry

Table 2. Percentage distribution of *Salmonella* serovars in the three LGAs studied in Plateau State

	Salmonella species/ (%)						
LGA	*S*. Gallinarum	S. Typhimurium	*S*. Typhi	*S*. Pullorum	*S*. Enteritidis	*S*. Parattyphi A	Total
Jos North	7 (14.3) [b]	0 (0.0) [b]	5 (12.2) [a]	1 (2.0)	1 (2.0)	0 (0.0) [b]	15 (30.6)
Jos South	16 (32.7) [a]	4 (8.2)[a]	3 (6.1) [b]	2 (4.1)	2 (4.1)	0 (0)[b]	26 (51.1)
Jos East	5 (10.2)[b]	0 (0.0) [b]	1 (2.0) [c]	0 (0.0)	0 (0.0)	1 (2.0)[a]	8 (17.0)
Total	28 (57.2)	4 (8.2)	10 (20.4)	3 (6.1)	3 (6.1)	1 (2.0)	49 (100)
ANOVA (F):	34.33	16.00	9.45	2.97	2.97	50.0	
P-value	0.008	0.025	0.050	0.194	0.194	0.005	
LOS	*	*	*	NS	NS	*	

***:** Significant at $p < 0.05$
NS: Not Significant
LOS: Level of significant
Values with different superscripts in the same column are significantly different

Table 3. Risk factors associated with *Salmonella* positive rate in Jos North, Jos South and Jos East LGAs studied in Plateau State

Risk factors	*Salmonella* result		OR (95% CI)	*P* value
	Positive n(%)	negative n(%)		
Vaccination status against *Salmonella*				
No	3(50.0)	1(50.0)	2.20(0.11-42.74)	0.47
Yes	5(31.2)	11(68.8)		
Administered antibiotics				
No	1(50.0)	1(50.0)	1.67(0.09-31.89)	0.64
Yes	6(37.5)	10(62.5)		
Movement from one pen to the other				
Yes	7(77.8)	2(22.2)	4.38(1.10-33.9)	0.17
No	4(44.4)	5(55.6)		
Storage of feed				
Within pen	5(100.0)	0(0.0)	0.00(1.20-3.89)	0.05
Stores	6(46.2)	7(53.8)		
Type of feed				
Local	9(62.2)	4(30.8)	3.38(0.39-28.7)	0.27
Commercial	2(40.0)	3(60.0)		
Use of footbath disinfection when entering the poultry house				
No	1(50.0)	1(50.0)	0.60(0.03-11.47)	0.64
Yes	10(62.5)	6(37.5)		
Biosecurity practice				
No	11(64.7)	6(35.3)	0.00 (0.19-0.67)	0.38
Yes	0(0.0)	1(100.0)		
Farm previously contaminated by *Salmonella*				
Yes	12(92.3)	1(7.7)	48.0 (2.40-958.2)	0.01*
No	1(20.0)	4(80.0)		

OR: Odds ratios; CI: Confidence interval
*: Significant at $p < 0.05$

Table 3. Risk factors associated with *Salmonella* positive rate in Jos North, Jos South and Jos East LGAs studied in Plateau State cont'd

Risk factors	*Salmonella* result		OR (95% CI)	*P value*
	Positive n(%)	negative n(%)		
Flock size				
<1000	3(100.0)	0(0.0)	0.00(undefined)	0.05
			Referent	
2000-4000	6(54.5)	5(45.5)	1.00(0.13-7.42)	0.67
5000-7000	0(0.0)	1(100.0)	0.00(undefined)	0.25
>7000	1(33.3)	2(66.7)	0.00(undefined)	0.20
Re-use of egg parking trays				
Yes	10(66.7)	5(33.3)	4.00(1.29-55.5)	0.33
No	1(33.3)	1(66.7)		
Trucks run and park near the entrance to poultry house				
Yes	6(100.0)	0(0.0)	0.00 (1.23-4.67)	0.03*
No	5(47.8)	7(58.9)		
Source of water				
Borehole	1(33.3)	2(66.7)	2.50 (0.0-195.5)	0.58
			Referent	
Tap	1(16.7)	5(83.3)	1.00(0.0-52.5)0.77	
Well	5(100.0)	0(0.0)	0.00(undefined)	0.03*
Overhead tank	4(22.2)	0(0.0)	0.00(undefined)	0.14
Presence of rodents				
Yes	9(81.8)	2(18.2)	11.25(1.19-106.13)	0.04*
No	2(28.6)	5(71.4)		
Presence of other farm animals				
Yes	10(62.5)	6(37.5)	1.67(0.09-31.91)	0.64
No	1(50.0)	1(50.0)		

OR: Odds ratios; CI: Confidence interval
*: Significant at $p < 0.05$

Plate 1. Characteristic transparent colonies with black centre by *Salmonella* species on SSA (as shown by the arrow)

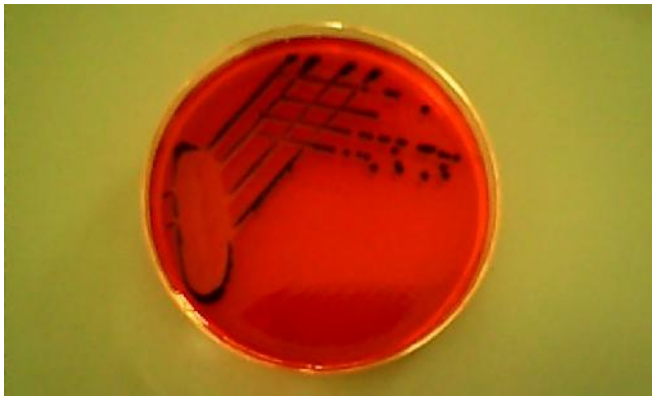

Plate 2. Characteristic red translucent colonies with black centre colonies by *Salmonella* species on XLD agar (as shown by the arrow)

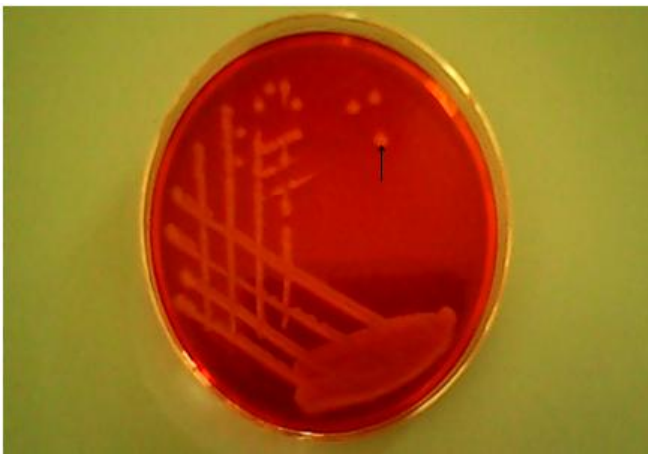

Plate 3. Characteristic pale red translucent colonies of *Salmonella* species on BGA (as shown by the arrow)

farms investigated. It also confirms the report of Anyanwu *et al.* (2010) who observed a pattern of *Salmonella* infection that appeared to be spreading among poultry farms in Nigeria, in the form of epizootics. The prevalence rate observed is of economic and public health significance for Plateau state and Nigeria. The result of this study also showed that the isolation rate in the three local government areas were significantly different ($p < 0.05$). The isolates in Jos South were significantly higher ($p < 0.05$) compared to Jos North and Jos East. This may be attributed to poor hygienic practices and poor implementation of biosecurity measures. The result is in agreement with the recent report of Mai *et al.* (2013) who documented high incidence rate (32.5%) of *Salmonella* species from external shell swab of table egg in Jos South LGA. The observed isolates in Jos North were statistically similar to Jos East ($p > 0.05$). It is important to state that one of the characteristic features observed during the study was the isolation of *S.* Typhimurium from human as well as poultry and feed samples, though there was no significant difference ($p > 0.05$) between this isolate in the various sources. This may be attributed to constant contact between feed, poultry birds and faecal droppings by farm handlers as was also reported by Vellinga and Van-loock (2002). This result is also not surprising as *S.* Typhimurium has been reported to have a broad host range and can infect both human and animals (Corry *et al.*, 2002). A large number of environmental factors including the poultry house environment, untreated drinking water, old litter, other farm animals, domestic pets, rodents, insects, wild birds, farm handlers, equipment and transport vehicles have been suggested as source of *Salmonella* infections in broiler and layer flocks, but the relative importance of these potential sources is not clearly understood (Garber *et al*., 2003; Meerburg, 2006).

This is the first reported study of the risk factors associated with *Salmonella* infection in poultry farms, Jos, Plateau State. Although there is scarce literature available on the risk factors associated with *Salmonella* infection in Jos, no published data exist on the subject matter prior to this study. Hence, the results of this study are discussed, compared and contrasted with studies in other part of the world. We found a significant protective effect of vaccination for *Salmonella* infection (OR 2.20; CI 95% 0.11-42.74). Vaccination has been advocated as a method of *Salmonella* control in farms for many years, and its practical efficacy has been supported by previous studies (Feberwee *et al*., 2001; Davies and Breslin, 2003a). Despite the strength of association as being protective, a large proportion of flocks in the present study already vaccinated against *Salmonella* have shown to have a small effect on lowering the overall *Salmonella* prevalence (10.9%). This might be attributed to inappropriate administration of vaccine dosage, reduced potency of the vaccine due to poor storage and a probable establishment of infection prior to vaccination.

Prophylactic use of antibiotics against bacterial infection, though, increased bacteria resistance but has been reported to reduce the number of colonized and shed bacteria (Velge *et al.*, 2005). Our findings showed administration of antibiotics (OR 1.67; CI 95% 0.09-31.9) to be significantly protective. Rose *et al*. (2000) reported an increased risk of *Salmonella* contamination associated with trucks running and parking in close vicinity to the poultry house. It is thus possible that chickens might be contaminated by mechanical carriage of *Salmonella* on the wheels of vehicles or on human footwear from areas of access to inside the premises. This is in agreement with our present study, which showed a significant association between trucks running and parking near the entrance of the poultry house ($p < 0.05$) and *Salmonella* contamination. Therefore, additional measures need to be implemented to guarantee an effective control of trucks running close to the poultry house. Commercial feed mills

Table 4. Risk factors for zoonotic Salmonellosis among poultry farm handlers in Jos North, Jos South and Jos East LGAs studied in Plateau state

Risk factors	*Salmonella* result		OR (95% CI)	*P* value
	Positive n(%)	negative n(%)		
Keep other avian husbandry at home				
Yes	10(76.9)	3(23.1)	2.22 (0.25-20.17)	0.43
No	3(60.0)	2(40.0)		
Change clothing after work				
Yes	5(83.3)	1(16.7)	2.50(0.21-29.25)	0.44
No	5(66.7)	4(33.3)		
Knowledge of salmonellosis				
No	11(84.6)	2(15.4)	8.25(1.00-85.6)	0.09
Yes	2(40.0)	3(60.0)		
Eating in poultry house				
Yes	12(70.6)	5(29.4)	0.00(undefined)	0.72
No	1(100.0)	0(0.0)		
Wash of hands after work				
No	6(85.7)	1(14.3)	3.43(0.29-39.6)	0.37
Yes	7(63.3)	4(36.4)		

OR: Odds ratios; CI: Confidence interval
*: Significant at $p < 0.05$

were often reported as potential sources of *Salmonella* for poultry flocks (Corry *et al.*, 2002; Okonkwo *et al*., 2010). In our study, there was no statistically significant association between commercial (OR 3.38; CI 95% 0.39-28.7) or local feed mills and *Salmonella* contamination. The heat treatment used in the pelleting process should have reduced the *Salmonella* feed contamination, as previously suggested (Jones and Richardson, 2004). The most common serovar identified in this study from feed was *S*. Typhimurium. This suggests that feed might be an important risk factor as route for transmitting *Salmonella* in poultry farms, hence, there is increased likelihood of farms testing positive for *Salmonella* in feeds as a result of the presence of rodents and insects, most especially, where access to feed storage sites are compromised by rodents, which was documented by Davis *et al*. (2004).

Davis and Breslin (2003) identified contaminated footwear as a potential risk for source of *Salmonella* contamination in poultry farm. In addition, Heyndrickx *et al*. (2002) reported that the introduction of portable material by visitors could be an important source of horizontal transmission of *Salmonella* in poultry farms. Contrary to our findings, the presence of footbath disinfection when entering the poultry house (OR 0.60; CI 95% 0.03-11.47) was most significantly associated with a reduced risk of *Salmonella* transmission in poultry farms by visitors. This shows that poultry farms that do not use footbath disinfection at the point of entrance into the poultry house and within different pens are at high odds of transmitting *Salmonella* into the poultry house. Similarly, Cardinale *et al.* (2004) indicated that the risk of flock colonization decreased in proportion to the number of visits by the poultry farm handlers. Statistically, there was significant association between *Salmonella* contamination and knowledge of salmonellosis among poultry farm handlers (OR 8.25; CI 95 % 1.00-85.6). Knowledge of salmonellosis was categorized base on mode of transmission/prevention and control of salmonellosis in poultry farms and symptoms associated with the disease. Generally, it was observed that most farm handlers are not knowledgeable about salmonellosis.

This could be attributed to their low level of education and exposure on related issues, which indicates lack of awareness on the disease. This, however, might have contributed to the high prevalence rate recorded in this study. The lack of knowledge have also increased the risk of exposure and transmission of *Salmonella* by the farm handlers to flocks as reported by several studies (Charles and Takayuki, 2010; Mai *et al*., 2013), especially with the recent up surge in poultry farming business in Jos. Furthermore, this was also linked to other biosafety practices such as changing of clothes (OR 2.22; CI 95% 0.25-20.17) at separate room after work by poultry farm handlers and washing of hands after work (OR 3.43; CI 95% 0.29-39.6). Though, there was no statistical significant association, *Salmonella* can be carried on clothing, hence, farm handlers should wear freshly laundered clothing daily, and visitors should be provided with clean protective clothing. Biosecurity practices in this study were categorized based on isolation, flock health and monitoring, good management practices and hygienic practices. Though, statistically there was no significant association ($P > 0.05$), probably, biosecurity

measures adopted on these farms have minimally reduced *Salmonella* introduction into the poultry house as suggested by Henken *et al*. (1992) in broiler flocks. This also suggests that farm handlers are important in transmitting *Salmonella* species to chicken flocks. These findings are in agreement with the results of previous study in which *Salmonella* infection in chickens were prevented by strict application of hygiene measures (Namata *et al*., 2008), including the risk reducing measures identified in this study. *Salmonella* contamination of the previous flock has been shown to be a major risk factor for source of contamination of subsequent flocks in poultry farms (Baggesen *et al.*, 1992; Angen *et al*., 1996). In our study, it was observed that most of the poultry farms with a history of salmonellosis (OR 48.0; CI 95% 2.40-958.2) were again found to be contaminated by *Salmonella*; *Salmonella* might persist in contaminated poultry houses where the standard of cleaning and disinfection is poor as also reported by Davis and Breslin (2003b). This shows that poultry farms that were previously contaminated by *Salmonella* have high odds of being contaminated compared to those that were not previously contaminated.

Previous studies have documented that the risk of contamination increased with the number of chickens housed in a cage (Mollenhorst *et al.*, 2005; Namata *et al*., 2006). Though in this study, there was no statistically significant association in the number of flock size (OR 1.00; CI 95% 0.13-7.42) with *Salmonella* contamination, as also reported by Angen *et al*. (1996) and contrary to several studies who reported that flock size was consistently associated with an increased risk of *Salmonella* species in laying hens (Namata *et al*., 2008; Hunear-Saluan *et al*., 2009). Consequently, poultry farms with increased number of flocks housed in a cage are more likely to be at risk of *Salmonella* contamination; probably because a higher flock size increases the number of susceptibility burden. Egg handling practices were also studied and the re-use of egg-parking containers (crates) (OR 4.17; CI 95% 0.29-55.5.8) shows no statistically significantly associated to *Salmonella* infection. However, the re-use of packing materials is considered as a potential risk and source of transmission of *Salmonella* infection if the re-use containers, mainly plastics are not disinfected appropriately (Shirota *et al.*, 2001) while common egg crates may be impractical to clean and disinfect, once a house has tested positive for *Salmonella*, the egg crates should be discarded to avoid commingling eggs from the positive house with eggs from other houses on the common egg crates.

Fris and Van (1995) reported that the risk for a flock to be *Salmonella* infected increases through hands, clothing and equipment when poultry farm handlers are allowed to move from one pen to the other and from one poultry farm to the other. This is in agreement with the present study, which showed significant association between movement from one pen to the other (OR 4.38; CI 95% 1.10-33.9) and *Salmonella* contamination. This shows that poultry farms engaged in such practice are at high odds of being contaminated with *Salmonella* as opposed to farms that did not. In a study by Meerburg (2006), he documented that significant rodent population, especially rats on farms has been associated with an increased risk of *Salmonella* to broiler houses. Similarly, Garber *et al.* (2003) reported that rodents can be long-term sources of *Salmonella* infection. The rodents can further amplify the number of pathogen present in the environment. The results of our findings showed that the presence of rodents on the farm (OR 11.25; CI 95% 1.19-106.13) has a significant association with *Salmonella* contamination and in the poultry farms. By implication, farms with significant number of rodents, especially rat, have high odds of *Salmonella* contamination within the farms compared to those that did not have rodents in their farms. These infected rodents may contaminate feed and water, which can then become a source for *Salmonella* colonization of the food system. A study conducted by Pearson *et al*. (1993) documented that water can be a persistent source of *Salmonella* on a broiler farm and providing untreated water was a risk factor for broiler flock colonization with *Salmonella*.

In addition, drinking water chlorination was associated with a reduced risk of colonization. In agreement with the present study, farms using untreated water ($p < 0.05$) as source of drinking water for chickens are more likely to be at high odds of *Salmonella* contamination compared to those that use treated water. The quality of water is of fundamental importance in poultry production because many birds have access to the same water source and a problem in the water quality would affect a great number of birds. *Salmonella* infection may originate from water contaminated by faeces and secretion of sick birds. In conclusion, the result of this study indicate that farms that were not properly cleaned and disinfected after previous contamination by *Salmonella and* the presence of rodents, may significantly increase the risk of *Salmonella* infections in broiler and layer flocks. This may significantly be reduced by application of specific hygienic and biosecurity measures during the rearing period preventing horizontal and vertical transmission of the organism via farm handlers and breeder flocks, respectively.

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